SYNOPSIS OF RESEARCH PROJECT

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9. Introduction

Groundnut (*Arachis hypogaea* L.) is a widely recognized and economically important oilseed crop. Groundnut is a cultivated legume species classified under the family Fabaceae, within the tribe Aeschynomeneae and the subtribe Stylosanthinae. There are two subspecies of cultivated groundnut, hypogaea and fastigiata. It is a self-pollinating, tropical annual legume, but some cross-pollination may occur in places with high bee activity (Nigam *et al.*, 2004).

Groundnut is considered the “King of Oilseeds”. It is known as groundnut, earthnut, monkey nut, and poor man’s cashew nut. Groundnut seeds contain 45.50% oil and about 25-30% protein, making it a dual-purpose crop valued for both oil extraction and direct consumption.

Groundnut is one of the three major oilseed crops in India, both in terms of cultivated area and overall production. Globally, it is grown over approximately 29.7 million hectares, producing around 50.8 million tonnes, with an mean productivity of about 17.1 quintals per hectare. China leads global groundnut production, followed by India.

Groundnut covers an area of 4.71 million ha in India along production of 10.18 million t and also productivity of 2163 kg/ha during 2024 (Anon. 2024). Groundnuts account for 31.7 % of total oilseed production in India and contribute about 28.3% total cultivated area under oilseeds.

In the current context of edible oil availability in India, nearly 65–70% of the domestic requirement is met through imports, leading to substantial expenditure of foreign exchange. This situation highlights the need to enhance both the productivity and production of groundnuts. At present, the crop exhibits relatively low yield levels in the country, indicating significant scope for improvement. Increasing groundnut productivity can play a important role in strengthening nutritional security as well as improving the livelihoods of the farming community.

Nitrogen (N) is vital for early vegetative growth, chlorophyll formation and overall plant vigour. Although groundnut is a Fabaceae crop capable of biological nitrogen fixation through symbiosis with *Rhizobium*, an initial starter dose of nitrogen is necessary during early growth stages before effective nodulation occurs. Adequate nitrogen improves leaf area development, photosynthetic efficiency and supports better peg formation and pod development in groundnut (Tekulu, K., 2024).

Phosphorus (P) is vital for root development, energy transfer (ATP), nodulation and nitrogen fixation. In groundnut, phosphorus is important for early root growth, flowering, peg penetration and pod formation (Tekulu, K., 2024). Summer groundnut often faces moisture and temperature stress, under which phosphorus helps in better root proliferation and efficient utilisation of nutrients, resulting in improved yield and kernel quality.

Potassium (K) is vital for enzyme activation, water regulation, photosynthate translocation and stress tolerance. In summer groundnut, potassium enhances drought and heat tolerance, improves disease resistance and ensures proper translocation of assimilates from leaves to developing pods. Adequate potassium nutrition also contributes to increased pod filling, shelling percentage and oil content (Patel *et al*., 2022).

Application of FYM improves soil structure by increasing aggregation, porosity and water-holding capacity, which is particularly important for groundnut as pod development occurs below ground. FYM supplies essential macro and micronutrients in small but balanced amounts and acts as a slow-release source of nutrients duration of crop growth period. It also enhances the nutrient use efficiency of applied chemical fertilizers.

In summer groundnut, where soils often face high temperature and moisture stress, FYM helps in maintaining soil moisture, reducing nutrient losses and improving crop

resilience. Regular application of FYM increases organic carbon in soil, sustains the fertility of soil and contributes to long-term productivity.

Biochar positively influences soil properties by improving soil structure, aggregation, porosity and water-holding capacity. These improvements are particularly beneficial in light-textured and degraded soils, where biochar helps in increasing moisture retention and reducing bulk density. Improved soil aeration and moisture availability support better root growth and nutrient available for crops.

Biochar has an important role in enhancing soil chemical properties. It increases soil pH in acidic soils, improves CEC and decrease nutrient leaching, especially of potassium, and nitrogen (Laird *et al*., 2010). The porous nature of biochar enables nutrient absorption and retention, making nutrients available to plants over a longer period and improving fertiliser-use efficiency.

From a biological perspective, biochar provides a favourable habitat for soil microorganisms (Lehmann *et al*., 2011). It's more surface area and pore spaces promote microbial colonisation, enhance nutrient cycling and support symbiotic associations like as nitrogen fixation and mycorrhizal activity. These biological interactions contribute to improved soil nutrients status and crop growth.

The nitrogen component of the bio-consortium includes free-living and symbiotic nitrogen-fixing bacteria *Rhizobium* and *Azospirillum*, which convert atmospheric nitrogen into plant-available forms (Bhattacharyya *et al*., 2012). This enhances nitrogen availability, promotes vegetative growth and improves chlorophyll content in groundnut. Effective nodulation is particularly important during early and mid-growth stages for sustained nitrogen supply.

Phosphorus-solubilising microorganisms (PSB) present in the bio-consortium release organic acids and enzymes that transform unavailable phosphorus into available forms (Richardson *et al*., 2009). Adequate phosphorus availability improves root development, flowering, peg penetration and pod formation in groundnut. PSB also improve phosphorus use efficiency and decrease reliance on chemical phosphorus fertilizers.

Potassium-solubilising or mobilizing bacteria (KSB) have an important role in releasing potassium from soil minerals and unavailable pools. Potassium is essential for enzyme activation, photosynthate translocation, stress tolerance and improvement in pod filling and oil content of groundnut. KSB enhance potassium availability and improves overall crop performance, especially under stress conditions.

Zinc is involved in enzyme activation, carbohydrate metabolism, protein synthesis and the regulation of plant hormones such as auxins. Adequate zinc nutrition promotes proper root development, internode elongation and leaf expansion. In crops like groundnut, zinc plays a role in nodulation, flowering and seed development, ultimately contributing to improved yield and quality (Hafeez *et al*., 2013).

Iron is a key component of chlorophyll synthesis and is essential for electron transport in photosynthesis and respiration. Although iron is abundant in most soils, its availability to plants is often limited under alkaline and calcareous conditions, leading to iron deficiency chlorosis. Adequate iron supply ensures proper chlorophyll formation, enhances photosynthetic efficiency and supports overall plant vigour (Rout and Sahoo., 2015).

Balanced application of Zn and Fe improves nutrient uptake, enhances stress tolerance and increases crop productivity. Integration of micronutrients with organic manures, biofertilizers and recommended fertilizer practices ensures better availability, efficient utilization and sustained soil fertility.

10. Practical Utility of the Research Project

Integration of biochar, FYM, biofertilizers and micronutrients (Zn and Fe) will provide a scientifically validated approach to improve crop growth and yield of groundnut.

Use of biochar along with reduced chemical fertilizers (75% RDF) will help in improving nutrient use efficiency and reducing dependency on sole chemical fertilizers.

The study will provide practical recommendation for correcting micronutrient deficiencies (Zn and Fe) commonly observed in calcareous and alkaline soils of Gujarat.

Improvement in soil fertility status will support the groundnut-based cropping systems in the region.

Economic analysis will help farmers identify cost-effective INM practices that ensure higher returns and benefit-cost ratio.

11. Objectives

1) To study the effect of integrated nutrient-management with enriched biochar and micronutrients on growth, yield and quality of summer groundnut.
2) To assess the influence of integrated nutrient management with enriched biochar and micronutrients on nutrient content and uptake by summer groundnut.
3) To evaluate the effect of integrated nutrient-management with enriched biochar and micronutrients on post-harvest soil fertility.

4) To workout economics of integrated nutrient-management with enriched biochar and micronutrients for summer groundnut.

12. Review of Literature

12.1 Effect of integrated nutrient-management with biofertilizers and FYM

12.1.1 Growth parameters

Karunakaran *et al*. (2010) performed an experiment at Karaikal in Puducherry to evaluate the impact of integrated nutrient-management on groundnut growth. Their findings showed that a progressive increase in RDF, from control to 75% and further up to 125%, resulted improvement in leaf area-index (LAI) and plant height. Moreover, the combined use of organic inputs along with different RDF levels further enhanced these growth parameters.

A field study was investigated by Ola *et al*. (2013) at the Agronomy Farm, Bikaner, to examine the impact of INM on groundnut growth. The findings found that the use of FYM at 8 t/ha with 50% of RDF significantly enhanced branches per plant, nodulation, and total chlorophyll concentration. This treatment was followed by vermicompost applied at 3 t/ha along with 50% RDF, which also showed notable improvement in these growth parameters.

Chaudhary *et al*. (2015) performed an experiment at Sardarkrushinagar, to evaluate the response of vermicompost and biofertilizers on groundnut growth. The study demonstrated that the use of 125% RDN by vermicompost significantly improved plant height at 60 DAS as well as at harvest.

Sarade *et al*. (2016) performed a trial on groundnut at Rahuri to examine the implication of the general-recommended dosage of fertilizers (GRDF) in mixed with organic inputs on performance of groundnut. The results obtained that the application of GRDF (25:50:00 kg N, P_2O_5, and K_2O per hectare) along with 5 t FYM per hectare significantly enhanced key growth attributes, including plant height, plant spread, branches per plant, and number of functional leaves.

Bhosale and Pisal (2017) investigated a field trial at College of Agriculture, Kolhapur, a study was under to study the influence of inorganic and organic inputs on the performance of groundnut. The results demonstrated that the use of 125% of the fertilizers dosage produced superior growth attributes, including plant height, functional leaves, leaf area, branches per plant, and dry matter. However, these results were found to be statistically relation with treatments involving 100% and 75% RDF applied through inorganic sources in combination with 25% nitrogen supplied through vermicompost.

A study conducted by Patel *et al*. (2022) at College Agronomy Farm, Anand. The study showed that the use of 50% nitrogen through poultry manure mix with seed inoculation using *Rhizobium* significantly enhanced plant growth at harvest in groundnut compared to rest treatments. However, this response was found to be statistically comparable with the use of 100% nitrogen through poultry manure, as well as 50% nitrogen supplied through castor cake along with *Rhizobium* seed treatment.

Kundu *et al*. (2023) investigated a field study at the trial farm of Mohanpur, West Bengal, to examine the influence of varietal selection and nutrient management on the growth parameters of groundnut. The results demonstred that the treatment involving 125% of RDF with *Rhizobium* inoculation increase the taller plant height and dry matter.

Paramsivan *et al*. (2024) performed a trial at the Agricultural farm, Killikulam, to investigate nutrient-management on growth of groundnut and obtained that in treatment 75% STCR + *Rhizobium* at 3 kg/ha + Humic acid at 20 kg/ ha + Poultry manure at 3 t/ha recorded the tallest plant and minimum days required to 50% flowering of groundnut.

12.1.2 Yield attributes and yield

A field study was performed by Kachot *et al*. (2001) at Junagadh. They observed that the mixed supplied of FYM at 20 t/ha + *Azotobacter* spp. + *Pseudomonas striata* and 100% RDF resulted in higher pod and haulm yields of groundnut than the control.

Karunakaran *et al*. (2010) carried out a field trial at Karaikal, Pondicherry, to evaluate the impact of nutrient-management on the yield attributes of groundnut. They obtained that the haulm and pod yield were higher at 125% RDF + Enriched Compost at 5 t/ha and followed by 125% RDF (17-34-54 N P K/ha) + FYM at 12.5 t/ha, RDF (17-34-54 N P K/ha) + enriched compost at 5 t/ha and RDF alone.

A field trial investigated by Ola *et al*. (2013) to look out the response of organic manures mixed with RDF on yield attributes and productivity of groundnut. The results revealed that the application of FYM at 8 t/ha with 50% RDF significantly increased kernels per plant, pods per plant, and overall yield relation to the control treatment.

Chaudhary *et al*. (2015) at Sardarkrushinagar to find out the impact of vermicompost and biofertilizers on yield attributes and productivity of groundnut. The results revealed that the application of 125% RDN through vermicompost significantly enhanced yield parameters, including total pods per plant, filled pods per plant and 100-kernel weight, compared to 75% RDN given by vermicompost. However, these results were found to be statistically related to the application of 100% RDN through vermicompost.

Sarade *et al*. (2016) investigated a trial on groundnut studies, the implication use of GRDF does and organic inputs on yield of groundnut at Rahuri and obtained higher yield parameters and shelling percentage of groundnut with the use of GRDF does, which was recorded and at par with 50% RDF + 50% N given by Neem cake, 75% RDF and 25% N applied by Vermicompost and 75% RDF and 25% N applied by FYM.

Bhosale and Pisal (2017) performed a field trial at the College of Agriculture, Kolhapur to seek out the results of the application of inorganic and organic inputs on yield attributes and production of groundnut. The studies revealed that treatment with the application of 125% RDF by inorganic fertilizers obtained the highest pods per plant and the weight of pods per plant in groundnut.

A field study conducted by Maurya *et al*. (2017) at BHU, Varanasi. They observed that an application of 75% NPK+ 25% N given by FYM and 60 kg S given by gypsum obtained significantly the high yield of groundnut, similar with 75% NPK+ 25% N given by vermicompost and 40 kg S given by gypsum as relation to other INM treatments.

Datta *et al*. (2018) performed a trial at the ICAR Research Complex for NEH Region, Lembucherra, Tripura. The results revealed that significantly higher weight of pod and kernel per plant in groundnut were recorded under treatment, where seeds were treated with *Rhizobium* culture and the crop received 50 kg P_2O_5 and 50 kg K_2O/ha.

Vala *et al*. (2018) at Junagadh evaluated the effects of inorganic inputs, biofertilizers, and FYM on groundnut yield parameters. They found the highest yield with the FYM and Biofertilizer treatment, using 75% RDF + 25% N.

Joshi and Patel (2021) conducted a field trial at the Agronomy farm, Sardarkrushinagar. The results found that the combined use of RDF along with *Rhizobium* and phosphate-solubilising bacteria (PSB) significantly increased pods per plant and dry pod weight in groundnut. This treatment was followed by 75% RDN supplemented with 25% nitrogen applied by vermicompost along with PSB and *Rhizobium*, and a similar combination involving 25% nitrogen applied by farmyard manure (FYM), both of which also demonstrated comparable improvements.

A study conducted by Patel *et al*. (2022) at College Agronomy Farm, Anand. The findings found that the use of 50% nitrogen supplied poultry manure in combination with *Rhizobium* seed inoculation significantly increased pods per plant in groundnut relation to remaining treatments.

Kundu *et al*. (2023) performed out a trial at the research farm of Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, to evaluate the impact of varietal selection

and nutrient-management on yield parameters of groundnut. The studies obtained that with the suppling of 125% RDF and *Rhizobium* inoculation showed the highest pods per plant, 100 kernel weight, pod yield, haulm yield.

Paramsivan *et al*. (2024) carried out a trail to seek out the effect of nutrient management on groundnut. The studies showed the providing of 75% STCR + *Rhizobium* at 3 kg/ha + Humic acid at 20 kg/ha and Poultry manure at 3 t/ha obtained the maximum pods per plant, 100 pods weight and 100 kernels weight of groundnut over the rest of the treatments.

12.1.3 Quality parameters

A field trial was performed by Kachot *et al*. (2001) at Junagadh. They recorded higher shelling (%), oil yield and protein content in groundnut than the control under the combined use of FYM at 20 t/ha + *Azotobacter* spp. + *Pseudomonas striata* and 100% RDF.

A field trial was conducted by Ola *et al*. (2013) to investigate the response of the suppling of organic manures with RDF on the quality of groundnut at the agronomy farm, Bikaner. They found higher oil concentration, protein concentration and oil yield in groundnut significantly due to the applied of FYM at 8 t/ha + 50% RDF.

Sarade *et al*. (2016) investigated a trial on groundnut and studied the implications of applied GRDF and organic inputs quality of groundnut at Rahuri, and obtained that the providing of 25 kg N + 5 t FYM/ha + 50 kg P_2O_5/ha obtained numerically higher oil value in groundnut than others treatments.

A study conducted by Patel *et al*. (2022) at College Agronomy Farm, Anand. They found that the suppling of 50% N by castor cake and Seed inoculated with *Rhizobium* resulted in higher protein value in the kernel.

Paramsivan *et al*. (2024) carried out a trial to find out the results of nutrient-management on the quality parameters of groundnut. The studies obtained that use of 75% STCR + *Rhizobium* at 3 kg/ha + Humic acid 20 kg/ha and Poultry manure at 3 t/ha recorded the more oil, protein concentration and production of groundnut followed by 75% STCR + 20 kg of humic acid/ ha and Poultry manure at 3 t/ha.

12.1.4 Nutrient content and uptake

A field trial was conducted by Kachot *et al*. (2001) at Junagadh to investigate the impacts of organic, inorganic and biological input of nutrients on nutrient content and intake and found that the N and K amounts and uptake were significantly increased by use of FYM at 20 t/ha + l00% RDF + *Azotobacter spp.* + *Pseudomonas striata* and others

similar with the furnished of 100% RDF + *Azotobacter* spp. + *Pseudomonas striata***,** FYM at 10 t/ha , 50% RDF and only 100% RDF.

Karunakaran *et al*. (2010) carried out a field investigation at Karaikal, Pondicherry to investigation the response of nutrient-management on nutrient amount and intake by groundnut and analysed higher N, K and P absorption by groundnut with the suppling of enriched compost at 5 t/ha and 125% RDF.

A study conducted by Maurya *et al*. (2017) at BHU, Varanasi. The studies about nutrients concentration in kernels and haulms of groundnut under nutrient management and obtained that nutrients concentration increased with use of 75% NPK+ 25% N given by FYM + 60 kg S given by gypsum and also nutrients uptake was greater than other INM treatments.

Vala *et al*. (2018) at Junagadh evaluated the response of inorganic inputs, biofertilizers and FYM on nutrient amount and intake by groundnut. They found out highest total N, P, K and S absorption by groundnut were observed in 75% RDF + Biofertilizer treatment + 25% N given by FYM.

Joshi and Patel (2021) conducted a field trial at the Agronomy Instructional Farm, Sardarkrushinagar. The study showed that the application of 100% RDF mixed with biofertilizers (*Rhizobium* and phosphate-solubilizing bacteria, PSB) finds in the highest nitrogen and phosphorus concentration as well as their absorption in groundnut. This treatment was followed by 75% RDN supplemented with 25% nitrogen supplied by vermicompost along with *Rhizobium* and PSB, and a similar combination with farmyard manure (FYM).

Gudade *et al*. (2022) obtained that the highest total nitrogen and potassium uptake in groundnut was achieved with the providing of 75% RDN combined with 25% nitrogen supplied through FYM. This treatment was simmilar with the use of 100% RDN, which also showed comparatively high nutrient intake.

A study conducted by Patel *et al*. (2022) at College Agronomy Farm, Anand. They analysed that significantly higher nitrogen concentration in kernel and haulm of groundnut at harvest. The results indicated that superior performance was achieved with the suppling of 50% nitrogen through castor cake mixed with *Rhizobium* seed inoculation.

A field investigation was conducted by Paramsivan *et al*. (2024) to find out the response of INM on nutrient concentration and uptake in groundnut. The results revealed that the use of 75% soil test crop response (STCR) along with *Rhizobium* inoculation at 3

kg/ha, humic acid at 20 kg/ha, and poultry manure at 3 t/ha significantly enhanced nitrogen, phosphorus, and potassium uptake relation to the remaining treatments.

12.1.5 Soil fertility status

Kachot *et al*. (2001) performed a field investigation at Junagadh to examine the impact of INM on soil fertility after groundnut cultivation. The findings showed that the supplying of FYM at 20 t/ha, along with 100% RDF and biofertilizers (*Azotobacter* spp. and *Pseudomonas striata*), significantly improves the availability of soil nitrogen and phosphorus.

Karunakaran *et al*. (2010) performed an experimental trial at Karaikal in Puducherry to seek out the impact of INM on soil fertility in groundnut cultivation. The results revealed that the treatment involving 125% RDF combined with enriched compost resulted in the highest availability of nitrogen and potassium in the soil, and was superior to the other treatments.

A study conducted by Maurya *et al*. (2017) at BHU, Varanasi. The studies obtained that the use of 75% NPK+ 25% N given by FYM and 60 kg S through gypsum resulted in the highest organic carbon related to other INM treatments.

Vala *et al*. (2018) at Junagadh Agricultural University, Junagadh, evaluated the effect of inorganic inputs, biofertilizers and FYM on soil status after groundnut harvest. It was observed status of soil at harvest that available N, P_2O_5 and sulphur availability was significantly enhanced with the supplying of 75% RDF supplemented with 25% nitrogen provided by FYM with biofertilizer inoculation.

A study conducted by Patel *et al*. (2022) at College Agronomy Farm, Anand. The study reported that the use of 100% nitrogen through farmyard manure resulted in a significantly higher level of available nitrogen in the soil. However, this effect was found to be statistically comparable with treatments receiving 100% nitrogen given by castor cake, vermicompost, and neem cake.

Kundu *et al*. (2023) investigated a field trial at the research farm, Mohanpur, West Bengal, to examine the response of varietal selection and the impact of nutrient management practices on soil fertility following groundnut harvest. The results showed that the use of of 75% recommended dose of fertilizers either alone or in combination with *Rhizobium* inoculation, maintained relatively better soil properties.

Paramsivan *et al*. (2024) performed a field trial to assess the impact of INM on soil status after groundnut harvest. The results showed that the treatment comprising 75% soil test crop response (STCR) along with *Rhizobium* inoculation at 3 kg/ha, humic acid at 20

kg/ha, and poultry manure at 3 t/ha recorded the highest availability of nitrogen, phosphorus, and potassium in the soil, and was significantly superior to the other treatments.

12.1.6 Economics

Kachot *et al*. (2001) conducted a field trial at Junagadh to evaluate the economic performance of different nutrient management practices in groundnut. The results indicated that the high returns were obtained with the application of 100% RDF alone. However, this treatment proved to be at par with integrated approaches involving 100% RDF combined with *Azotobacter* spp. and *Pseudomonas striata*, FYM at 20 t/ha along with 100% RDF and biofertilizers, FYM at 10 t/ha with 50% RDF and biofertilizers, and FYM at 10 t/ha combined with 50% RDF.

Karunakaran *et al*. (2010) performed a field study at Karaikal in Puducherry to find out the economic implications of integrated nutrient management in groundnut cultivation. The results showed that the application of RDF alone resulted in the highest net returns and benefit–cost (B:C) ratio across both years of the study. In contrast, treatments involving organic manures and their combinations with different RDF levels incurred higher cultivation costs and were comparatively less economical.

A study conducted by Chaudhary *et al*. (2015) at Sardarkrushinagar evaluated the economic impact of INM in groundnut cultivation. The results indicated that the highest returns were obtained with the application of 125% RDN through vermicompost, whereas the maximum benefit–cost (B:C) ratio was recorded under the treatment involving 75% RDN applied through organic sources.

Vala *et al*. (2018) at College of Agriculture, Junagadh Agricultural University, Junagadh evaluated the effect of inorganic fertilizers, biofertilizers and FYM on economics of groundnut. Economic analysis of the treatments indicated that the combined application of 75% RDF along with 25% nitrogen supplied given by FYM and biofertilizer resulted in the highest gross returns, net returns, and benefit–cost (B:C) ratio. This was followed by the treatment involving 75% RDF mixed with 25% nitrogen given by vermicompost along with biofertilizers, and the supply of 75% RDF supplemented with 25% nitrogen given by FYM.

Datta *et al*. (2018) investigated a field trial at the ICAR Research Complex for NEH Region, Lembucherra, Tripura during three consecutive *kharif* seasons. They studied the economics of groundnut under INM and observed significantly higher gross returns and net returns with the treatment of groundnut seed with *Rhizobium* culture. This

performance was achieved when the treatment was supplemented with soil application of 50 kg P_2O_5 and 50 kg K_2O per hectare, which proved superior to all other treatments.

Joshi and Patel (2021) conducted a field trial during the summer season of 2018 at the Agronomy Instructional Farm, Sardarkrushinagar. The findings revealed that the highest returns and benefit–cost (B:C) ratio were achieved with the supplying of the RDF in combination with *Rhizobium* and phosphate-solubilising bacteria (PSB). This was after the treatments involving 75% recommended nitrogen dose supplemented with 25% nitrogen provided by vermicompost along with *Rhizobium* and PSB, and a similar combination using FYM.

Patel *et al*. (2022) conducted field studies at the Agronomy Farm, Anand, to seek out the economic efficiency of different nutrient management practices in groundnut. The findings indicated that the highest benefit–cost (B:C) ratio was found with the use of 50% nitrogen given by poultry manure combined with *Rhizobium* seed inoculation.

Kundu *et al*. (2023) investigated a field trial at the research farm at Mohanpur, West Bengal, to find out the impact of varietal selection and nutrient-management on the economics of groundnut. The studies found that the use of 100% RDF and *Rhizobium* inoculation recorded maximum economic returns with a B: C ratio.

A field trial was done by Paramsivan et al. (2024) to examine the economics of INM on groundnuts. According to their studies, the good treatment for net income and a B:C ratio in groundnuts was the use of STCR fertilizer as 75% STCR NPK/ha with humic acid at 20 kg/ha, Rhizobium 3 kg/ha and poultry manure at 3 t/ha. The above was after by the treatment of 75% STCR + Humic acid 20 kg/ha and Poultry manure at 3 t/ha.

12.2 Effect of integrated nutrient management with micronutrients

12.2.1 Growth parameters

Der et al. (2015) carried out a field study on groundnuts in the summer at the Instructional Farm, Junagadh Agricultural University, Junagadh, to seek out the impact of foliar application of potash and micronutrients on groundnut growth. They obtained that applying foliar sprays of K 0.5%, Fe 0.5%, Zn at 0.5%, and B at 0.2% at 40 DAS resulted in noticeably greater plant height, branches per plant, dry matter at 45 and 75 DAS, and nodules per plant.

Rahevar et al. (2015) investigated the impact of soil application of FYM with a combination of Fe and Zn on groundnut growth in an agronomical farm at Sardarkrushinagar. The application of FYM at 5 t/ha with 5 kg Fe/ha and 4 kg Zn/ha resulted in increased plant height and dry matter, according to the studies.

Immanuel *et al.* (2023) investigated a trial at Experimental Farm at Chandirambadi in Vandavasi, Tiruvannamalai, Tamil Nadu to study the integrated impact of organic inputs, NPK and foliar fertilization on groundnut. The results indicated high plant height and high effective nodules per plant with the providing of 100% RDF mixed with vermicompost at 4 t/ha + Zn-EDTA Foliar spray at 0.5% to Groundnut and Foliar spray to Pigeon pea (2% DAP & NAA 40 ppm).

Kumar *et al.* (2023) performed a trial on groundnut at SHUATS Prayagraj to examine the response of micronutrients on groundnut and obtained taller plant height, maximum nodules per plant, plant weight and CGR and RGR with the use of Zn + B (0.5% + 0.2%) (Foliar) with variety Kadiri 6.

Jagasia *et al.* (2024) performed a field study at Thane on groundnut to find out the influence of sulphur and foliar application of micronutrients on groundnut. The results showed that the use of 60 kg/ha of sulphur in conjunction with a foliar application of micronutrients (Cu 1.0 per cent, Zn 3.0 per cent, Mn 1.0 per cent, and Fe 2.5 per cent, B 0.5 per cent and Mo 0.1 per cent) exhibited the best attributes as evidenced by the plant height and dry weight.

12.2.2 Yield and yield attributes

Mohapatra and Dixit (2010) conducted a field investigation at Berhampur and evaluated the impact of combined use of FYM, recommended fertilizer dosage, Rhizobium, gypsum and boron on the performance of groundnut. The results obtained integrated application of FYM at 5 t/ha + 75% RDF + *Rhizobium* + gypsum at 250 kg/ha and B at 1 kg/ha recorded a higher pod yield over all other treatments.

A field trial was done by Der *et al*. (2015) at the Instructional Farm, Junagadh Agricultural University, Junagadh, on groundnut to examine the impact of foliar application of potash and micronutrients on yield parameters of groundnut. They found that combined foliar spray of K at 0.5%, Fe at 0.5%, Zn at 0.5% and B at 0.2% at 40 DAS recorded higher pod weight, 100 kernel weight, pod yield and haulm yield.

Rahevar et al. (2015) noticed the impact of FYM soil application combined with Fe and Zn on groundnut yield at an agronomic farm, Sardarkrushinagar. The treatment FYM at 5 t/ha with 5 kg Fe/ha and 4 kg Zn/ha had greater yields, according to the data.

A experiment was performed by Rajitha *et al.* (2019) and observed maximum harvest index (%) along with the treatment RDF + foliar spray of one per cent each of $CaNO_3$, $MgNO_3$ and sulphur + micronutrient mixture at 0.2 per cent which was statistically

at par with RDF + foliar spray of one per cent each of $CaNO_3$, $MgNO_3$ and sulphur + $ZnSO_4$ at 0.2 % and RDF + foliar spray of one per cent each of $CaNO_3$, $MgNO_3$ and sulphur.

Immanuel *et al.* (2023) performed a field trial at Experimental Farm at Chandirambadi in Vandavasi, Tiruvannamalai, Tamil Nadu to study integrated effects of manuring, NPK and foliar fertilization on the yield of groundnut. The studies found that maximum pods per plant, shelling, pod yield and kernel yield were observed under application of 100% RDF along with vermicompost at 4 t/ha + Zn-EDTA foliar spray at 0.5% to Groundnut.

Kumar *et al.* (2023) performed a trial on groundnut at SHUATS Prayagraj to evaluate the implication of micronutrients on groundnut and found a higher pods per plant and yield with the supply of Zn + B (0.5% + 0.2%) (Foliar) with variety Kadiri 6.

Jagasia *et al.* (2024) performed a field investigation at Thane on groundnut to examine the response of sulphur and foliar application of micronutrients on groundnut. They found that the use of 60 kg/ha of sulphur in conjunction with a foliar application of micronutrients Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%) B (0.5%) and Mo (0.1%), has exhibited the best attributes as evidenced by pod weight, seed weight and 100 seed weight.

12.2.3 Quality parameters

Rahevar et al. (2015) studied the response of soil use of FYM with a combination of Fe and Zn on groundnut quality parameters at an agronomical farm at Chimanbhai Patel College of Agriculture, Dantiwada Agricultural University, Sardarkrushinagar. They observed that applying FYM at 5 t/ha with 5 kg Fe/ha and 4 kg Zn/ha significantly improved quality parameters.

Immanuel *et al.* (2023) studied a trial at Experimental Farm at Chandirambadi in Vandavasi, Tiruvannamalai, Tamil Nadu to study integrated effects of organic manuring, NPK and foliar fertilization on quality parameters and obtained significantly highest oil content (49.74%) and crude protein (26.38) content in application of 100% RDF along with vermicompost at 4 t/ha and Zn-EDTA foliar spray at 0.5% to Groundnut.

12.2.4 Nutrient content and uptake

Mohapatra and Dixit (2010) performed a field study at Berhampur to evaluate the impact of integrated use of FYM, recommended fertiliser dosage, *Rhizobium*, gypsum and boron on nutrient concentration and absorption by groundnut. The results showed highest uptake of nutrients with the combined use of FYM at 5 t/ha + 75% recommended fertiliser + *Rhizobium* + gypsum and B.

Rajitha et al. (2019) performed a field investigation and noticed that applying RDF with foliar application of 1% each of CaNO3, MgNO3, and sulfur + micronutrient mixture at 0.2% findings in the significantly largest absorption of phosphorus, nitrogen, and potassium at harvest.

Jagasia *et al.* (2024) performed a field investigation at Thane on groundnut to seek out the response of sulphur and foliar application of micronutrients on nutrients value and absorption of groundnut and observed that the use of 60 kg per hactre of elemental sulphur in conjunction with a foliar application of micronutrients (Cu (1.0%), Zn (3.0%), Mn (1.0%), and Fe (2.5%) B (0.5%) and Mo (0.1%), has exhibited the best attributes as evidenced by oil content, and protein value.

12.2.5 Soil fertility status

In a field study at Berhampur, Mohapatra and Dixit (2010) assessed the impact on soil fertility of the combined use of FYM, gypsum, boron, Rhizobium, and the recommended fertilizer dosage. According to the tests, available N in the soil increased following groundnut harvest in all treatments and integrated application of FYM + 75% recommended fertilizer dosage + Rhizobium + gypsum and boron. However, available P dropped as a result of fixation in acidic soil, and the P balance was negative.

12.2.6 Economics

In a field trial in Berhampur, Mohapatra and Dixit (2010) assessed the impact on groundnut economics of integrated usage of FYM, recommended fertilizer dosage, Rhizobium, gypsum, and boron. The application of FYM + 75% RDF + Rhizobium + gypsum + B produced the highest net returns and B:C ratio.

Rahevar et al. (2015) find out the impact of FYM soil application with a combination of Fe and Zn on groundnut economics at an agronomical farm at Sardarkrushinagar. They found that applying FYM at 5 t/ha with 5 kg Fe/ha and 4 kg Zn/ha produced the high B:C ratio in groundnut crops.

Immanuel *et al.* (2023) performed a field investigation at Experimental Farm at Chandirambadi in Vandavasi, Tiruvannamalai, Tamil Nadu to study integrated effects of organic manuring, NPK and foliar fertilization on economics. The studies showed that use of 75% RDF + Vermicompost (5 t/ha) + Zn-EDTA Foliar spray at 0.5% to Groundnut obtained the highest B:C ratio.

12.3 Effect of integrated nutrient-management with biochar

12.3.1 Growth parameters

Wacal *et al*. (2019) performed a trial at the Tottori Prefecture, Japan, to find out the response of the use of mixture of biochar with RDF on the growth of sesamum and recorded that use of RDF with biochar significantly increases plant's height and branches per plant.

Gudade *et al*. (2022) carried out a trial at Umiam, Meghalaya, to research results of biochar levels and integrated nutrient-management practices on agro-physiological performance and producation of maize. The studies observed significantly higher plant height, dry matter accumulation and crop growth rate with the application of biochar at 15 t/ha and similar results were obtained with the second factor, 75% RDN + 25% FYM.

Sarwar et al. (2023) conducted a field investigation at the Agronomic Research Farm in Multan, Pakistan, to examine the effects of integrated nutrient-management on a maize and wheat cropping system during the summer and winter seasons. They discovered that applying 75% NPK and 5 t/ha biochar increased dry matter and leaves per plant.

An experiment trial was conducted by Bajpayee *et al*. (2025) at the farm of Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore, to study sustainable nutrient-management strategies for enhancing soybean productivity through biochar and manure integration. They obtained the highest plant height, leaf per plant and branches per plant under treatment 50% Fertilizer dosage + 2.5 t/ha biochar and 2.5 t/ ha Vermicompost in soybean.

According to Hamissou et al. (2025), the 2% biochar treatment had the highest outcomes, followed by the 10% and 5% biochar treatments. This resulted in much higher tomato stem height and more leaves.

Yadav *et al*. (2025) conducted field trials on rice at the agronomy research farm Kanpur and observed that mixer application of 100% recommended fertilizers dosage with 5 t/ha FYM, 5 kg Zn/ha and biochar recorded the taller plant height, maximum tillers and dry matter accumulation compared to the other treatments.

12.3.2 Yield and yield attributes

In a field study in Tottori Prefecture, Japan, Wacal et al. (2019) examined the impact of applying a mixture of biochar and RDF on sesame yield. They found that the higher rate of biochar addition considerably increased the sesame seed yield in the first cropping when compared to the control.

Gudade *et al*. (2022) performed an experiment at Umiam, Meghalaya, to seek out implications of biochar levels and integrated nutrient-management practices on agro-physiological performance and production of maize. The results demonstrated that significantly higher kernel yield was obtained with the supply of 50% RDN and 50% FYM, which was at par with biochar at 15 t/ha. Application of 75% RDN and 25% FYM resulted in the highest stover yield.

At Agronomic Research Farm, Multan, Pakistan, Sarwar et al. (2023) planned a field experiment to examine the effects of integrated nutrient-management on a maize and wheat cropping system during the summer and winter seasons. Applying 75% NPK + 5 t/ha biochar allowed them to achieve a maximum 1000 grain weight, yield parameters, and harvest index.

A field trial was performed by Bajpayee *et al*. (2025) at farm of Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore, to study sustainable nutrient-management strategies for enhancing soybean productivity through biochar and manure integration. They found that the highest seed and straw yield was under treatment 50% RDF + 2.5 t/ha biochar + 2.5 t/ha Vermicompost in soybean.

Hamissou *et al*. (2025) highest yield obtained with 2% biochar. Yield at 5% biochar, although lower than at 2%, was still higher than the control.

A field trial was investigated by Sriram *et al*. (2025) during late *kharif*, 2024 at the Agricultural Farm, Bapatla and resulted that the combined use of 100% RDF and biochar at 4 t/ha leads to the highest values for dry matter production, yield components

Yadav *et al*. (2025) conducted field trials on rice at the agronomy farm, Kanpur. The results showed that the yield parameters of rice were significantly improved under treatment consisting of 100% RDF + biochar + 5 t/ha FYM and 5 kg Zn/h. They recorded maximum panicle length, number of grains per panicle, test weight, effective tillers, seed yield and straw yield in relation to the control and remaining nutrient treatments.

12.3.3 Nutrient content and uptake

Khan *et al*. (2020) performed a pot trial at Huazhong Agricultural University in China and observed an increase in nitrogen content of the shoot of rapeseed, increasing with biochar and nitrogen levels, and an improves of 42% at 45 DAS and 22% at 60 DAS was observed in shoot nitrogen content for biochar 15 t/ha + NPK treatment related to no biochar + NPK.

Sarwar *et al*. (2023) obtained that the application of biochar in integrated nutrient application (75% NPK and 5 t/ha biochar) resulted in more uptake of nutrients (N, P, K, Ca, Mg, Zn) in maize.

A field investigation was performed on groundnut by Sriram *et al*. (2025) at the Agricultural Farm, Bapatla, to examine the combined effect of fertilizers and biochar on of groundnut. The studies obtained that the mixed use of 100% RDF + biochar at 4 t/ha led to the highest values for nutrient uptake.

12.3.4 Soil fertility status

In a field study in Tottori Prefecture, Japan, Wacal et al. (2019) found the response of applying a mixture of biochar and RDF on sesamum growth. They discovered that adding biochar to the first cropping considerably raised soil EC, C:N ratio, exchangeable K, and soil cation exchange capacity (CEC) in relation to the control treatment.

Khan *et al*. (2020) performed a pot experiment at Huazhong Agricultural University in China and observed that total nitrogen, available phosphorus and potassium were improved by the combined application of biochar and nitrogenous fertilizers.

Sriram et al. (2025) investigated a field study on groundnuts at the Agricultural Farm in Bapatla to examine the combined impact of biochar and fertilizers on groundnut performance. The results demonstrated that the maximum water holding capacity (128.6%), organic carbon (79.2%), and porosity (33.87%) were obtained by applying 100% RDF and biochar at a rate of 4 t/ha.

12.3.5 Economics

Gudade et al. (2022) seek out the impact of biochar levels and integrated nutrient-management techniques on agro-physiological performance of maize at Umiam, Meghalaya. The maximum gross yields with biochar at 15 t/ha were substantially higher than those under all other treatments, according to the studies. Biochar at 5 t/ha produced the highest net returns, which were considerably higher than the other treatments and statistically related to biochar at 10 t/ha.

Sarwar et al. (2023) investigated a field study at Agronomic Farm, Multan, Pakistan, to examine the response of integrated nutrient-management on a maize and wheat cropping system during the summer and winter seasons. They found that the 75% NPK and 5 t/ha biochar treatment was more economically sound than other treatments.

13. Materials and Methods

13.1 Location : Instructional Farm, Department of

13.2 Year and season of experiment : Summer, 2026 & 2027

13.3 Experiment design : Randomized Block Design (RBD)

Experimental details

Crop and variety	: Groundnut, GG 37
Spacing	: 30 cm
Plot size	: Gross plot: 5.0 m x 2.7 m (9 rows) Net plot: 4.0 m x 1.5 m (5 rows)
Seed rate	: 130 kg/ha
Recommended dose of fertilizers	: As per treatment
Number of treatments	: 12 (Twelve)

13.4 Treatments details:

T_1 Control (No fertilizer)

T_2 100% RDF (25:50:50 N: P_2O_5: K_2O kg/ha)

T_3 75% RDF + FYM at 5 t/ha

T_4 75% RDF + FYM at 5 t/ha + Bio consortia (N, P, K) at 2 lit/ha

T_5 75% RDF + FYM at 5 t/ha + Biochar at 1 t/ha

T_6 75% RDF + FYM at 5 t/ha + Bio consortium (N, P, K) at 2lit/ha + Biochar at 1 t/ha

T_7 75% RDF + FYM at 5 t/ha + Enriched Biochar at 1 t/ha

T_8 75% RDF + FYM at 5 t/ha + Bio consortium (N, P, K) at 2lit/ha + $ZnSO_4$ at 10 kg/ha

T_9 75% RDF + FYM at 5 t/ha + Bio consortium (N, P, K) at 2lit/ha + $FeSO_4$ at 25 kg/ha

T_{10} 75% RDF + FYM at 5 t/ha + Enriched Biochar at 1 t/ha + ZnSO4at 10 kg/ha

T_{11} 75% RDF + FYM at 5 t/ha + Enriched Biochar at 1 t/ha + $FeSO_4$ at 25 kg/ha

T_{12} 75% RDF + FYM at 5 t/ha + Enriched Biochar at 1 t/ha + $ZnSO_4$ at 10 kg/ha + $FeSO_4$ at 25 kg/ha

Note: -

1. RDF (25-50-50 kg N-P_2O_5-K_2O kg/ha) will be applied as per treatments
2. Biochar will be use prepared by the Department of Renewable Energy Engineering
3. Biochar will be enriched using a liquid formulation of NPK consortia at 2.0 l/ha.
4. The enriched biochar will be incubated for 10 days prior to soil application.

13.5 No. of replications : 3 (Three)

13.6 Observation to be recorded

A. Plant population

1) Initial Plant population (20DAS)

2) Final Plant population

B. Growth parameters

1) Plant height (cm) at 30, 60,90 DAS and at harvest

2) Numbers of branches per plant at 30, 60,90 DAS and at harvest

3) Dry matter accumulation per plant (g) at 30, 60,90 DAS and at harvest

4) Number of root nodules per plant at 45 DAS

5) Dry weight of root nodules per plant (mg) at 45 DAS

6) Relative growth rate

7) Crop growth rate

C. Yield attributes, and yield

1) Number of pods per plant

2) Weight of pods per plant (g)

3) 100 kernels weigh (g)

4) Pod yield (kg/ha)

5) Haulm yield (kg/ha)

6) Harvest index (%)

D. Quality parameter

1) Oil content (%)

2) Oil yield (kg/ha)

3) Shelling percentage

E. Nutrient content and uptake

1) Nutrient content N, P, K, Fe and Zn (%) in pod and haulm

2) Nutrient uptake N, P, K, Fe and Zn by pod and haulm

F. Soil fertility status

1) Soil Organic carbon

2) Available N, P_2O_5, K_2O, Fe and Zn

3) Total microbial count

G. Economics

1) Cost of cultivation

2) Gross return

3) Net return

4) B:C ratio

14. Statistical Analysis

The data will be subjected to statistical analysis by adopting appropriate analysis of variance as described by Gomez and Gomez (1984). Wherever the F values found significant at 5% level of probability, the critical difference (CD) values/DNMRT will be computed for making comparison among the treatment means. In order to establish

interrelationship between various components, coefficients of correlation and regression equations will be computed as described by Panse and Sukhatme (1985).

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